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Treatment and Disposal of Poultry Processing Wastewater in Sri Lanka

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***Abstract*—**Discharge of untreated poultry processing wastewater (PPWW) causes various environmental pollution issues in the receiving environment of water, land, and air. Treatment and disposal of PPWW in compliance with disposal norms is one of the main concerns of poultry meat production industries in Sri Lanka. In many countries, PPWW is treated using either Anaerobic Biological Treatments (ANERBTs) incorporated with energy recovery or Aerobic Biological Treatments (AERBTs) and discharged into municipal sewage systems for further treatment. The primary aim of this paper is to estimate organic strength characteristics (OSCs) of untreated PPWW in terms of COD and to provide an overview of the existing treatment technologies, its compatibility, and treated wastewater (TWW) disposal practices since no sound written documents or scientific studies done in Sri Lanka are reported. In this study, COD of untreated PPWW was used to determine its OSCs and compatibility of treatment techniques of existing treatment facilities. The field sample analysis reported COD of above 1,605mg/l assuring high OSCs of PPWW and evaluation of existing treatment methodologies surprisingly highlighted a very few applications of ANRBTs in the local PPIs, though ample research evidence is available on the application of ANRBTs for the treatment of wastewaters with high OSCs.

***Keywords*—**Poultry processing wastewater, treatment, disposal, aerobic, anaerobic

I. Introduction

A. *Poultry processing industry in Sri Lanka*

Poultry processing (PP) has become one of the fast growing industry sectors worldwide with an increasing trend of environmental pollution issues associated with the discharge of untreated or partially treated wastewater. Most of the pollution issues are directly related to groundwater and surface water contamination while the rest of the issues are related to atmospheric pollution through gaseous emissions, especially the Greenhouse Gas (GHG) emissions of methane (CH_4), carbon dioxide (CO_2), and nitrous oxide (N_2O) that leads to global warming.

In Sri Lanka, over the past few decades, PPI sector has developed from its level of backyard system into commercial status with modern facilities due to the increasing trend of chicken meat consumption in the country. Throughout this period, in particular, the broiler sector has shown prominent growth due to the active participation of the private sector (Department of Census and Statistics [DCS] 2014). Abeyratne (1996) stated that between 1983 and 1989, poultry production has multiplied by a factor of 5, and between 1990 and 1994; average per capita chicken meat consumption has increased by 150 percent. The upward trend of increasing chicken meat consumption has directed the PP sector in Sri Lanka to extend its basic operations of Poultry First Processing (PFP) or slaughtering to poultry further processing or second processing. The PFP or slaughtering produces wholesome chilled, packed chicken from live chicken for human consumption through a series of processing steps whereas poultry further processing produces different chicken meat products from processed birds produced by the first processing plants.

According to Alahakoon, *et al*. (2016), during the year 2010, three (03) large scale and ten (10) medium scale PFP establishments and seven (07) Poultry first and further processing (PFFP) plants were in operation over the country, accounting to a total of 13 PFPs and 07 PFFP plants. It further reported the existence of many small-scale retailers who sell chicken meat independently throughout the country. The preliminary data survey of this study explored twenty-three (23) PPIs registered in the Department of Animal Production and Health (DAPH); sixteen (16) PFPIs and seven (07) PFFPIs. In addition, the existence of a few small scale unregistered PFPIs and several other domestic scale poultry slaughtering establishments were explored. As per the information of Poultry Processors' Association, PPI sector in Sri Lanka is categorized into two main categories depending on its daily production; large scale and medium scale: large scale, where more than 15,000 birds are processed in a day, and medium scale where 5,000-15,000 birds are processed

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in a day.

B. Poultry meat production and wastewater discharge

Poultry processing operation converts live chicken into safe and wholesome meat products suitable for human consumption through a series of processing steps. The PP is basically a highly coordinated system of mechanized operations that kills the bird, remove inedible portions, package/preserve the edible portions and distribute to the consumer. The PFP operations include birds unloading, stunning, killing, bleeding, scalding, de-feathering, evisceration, chilling, freezing, and packing (Sams, 2000) whereas the second processing or further processing includes a variety of unit operations such as size reduction, mixing, or blending with ingredients, forming or stuffing, smoking, cooking or heating, cooling, peeling, slicing, packaging, labeling, and distribution depending on the desired product.

In the poultry meat production process, water is primarily used for the cleaning of products in various process steps, cleaning of machineries and equipment and production floor washings etc. Therefore, poultry meat production results in generating a large amount of wastewater contaminated with biodegradable organic pollutants. The quantity of water used varies from one another depending on the process steps and specific measures implemented to minimize water usage, hence to reduce the wastewater treatment cost. Gerber, *et al*., (2005) emphasized that typical water usage in poultry slaughterhouses ranges from 6 to 30 cubic meters per ton of product. Veerkamp (1999) reported that in the Netherlands, the total potable water required to process a single bird varied between 5-20 liters and Avula, *et al*., (2009) reported that in several European operations, potable water requirement is 26.5 liters per bird during primary and secondary processing with the suggestion for ultrafiltration as a means of recycling water. According to (Barbut, 2015), cleaning operations account for 30-50% of the total daily water consumption.

C. Characteristics of poultry processing wastewater and environmental impacts

The principal constituents of poultry processing wastewater include blood, solubilized fats, and proteins present in both particulate and dissolved forms, feces, Nutrients (Nitrogen and Phosphorus), and various species of water borne microorganisms. In addition, poultry industry wastewater may contain residues of chemicals such as disinfectants and detergents used for disinfection and cleaning activities. These contaminants characterize the poultry processing wastewater in terms of major pollution parameters of COD, Biochemical Oxygen Demand (BOD), Total Kjeldhal Nitrogen (TKN), Ammonia Nitrogen (NH3-N), Total Phosphorous (TP), Total suspended Solid (TSS), Fats, Oil and Grease (FOG) and pathogenic organisms etc. World Bank, (2007) reported that BOD and COD of poultry processing wastewater is high due to the presence of organic materials such as blood, fat, flesh, and excreta. Blood has the highest COD strength of any liquid effluent arising from both large animal and poultry slaughter houses (European Commission, 2005). The characteristics of poultry processing wastewater estimated through a study conducted in the year 2005 by Arvanitoyannis Ladas 2008) reported BOD of 2030 to 4200 mg/L, COD of 3980 to 7120 mg/L and TSS of 285 to 2660 mg/L in the poultry processing wastewater. Merka (1989) reported final effluent with an average BOD of 2178 mg/L, COD of 3772 mg/L, TSS of 1745 mg/L, FOG of 776 mg/L, TKN of 129 mg/L and Ammonia of 13 mg/L.

The past scientific studies reported various adverse impacts due to biological decomposition of organic material or COD/BOD taken place in both the environmental conditions of oxygen rich and oxygen poor:, namely aerobic biological and anaerobic biological degradation. The most commonly reported serious adverse impacts upon discharge of untreated PPWW with high organic strength is the deterioration of receiving freshwater bodies posing a great risk on its ecosystems, animals, and human health resulting in unsatisfactory drinking water, death of fish, planktons, and other living organisms through depletion of dissolved oxygen in the water due to microbial decomposition of biodegradable organic material represented by high BOD and COD.

The high levels of uncollected blood in the PPWW cause the presence of Nitrogen (N) in form of NH_3-N, Nitrates (NO_3^-), Nitrites (NO^{2-}), P, and various species of waterborne microorganisms such as pathogens including *Salmonella* and *Campylobacter* (World Bank, 2007). The formation of oil and grease layers on the water surfaces and increased turbidity represented by high TSS causes cutting off of oxygen transfer and sunlight penetration into water bodies.

Poultry processing wastewater may contain up to 100 different species of micro-organisms introduced when the feathers, feet, and intestinal contents are removed and these microorganisms include potential pathogens such as *salmonella sp., staphylococcus sp.*, and *clostridium sp.* (Salminen, Rintala, 2002). Discharge of waterborne microorganisms including pathogens contributed from poultry processing causes serious adverse health impacts on humans and animals through contaminated drinking water in the receiving water bodies. Some of the pathogens that are known to be transmitted through contaminated drinking water lead to severe and sometimes life-threatening diseases such as typhoid, cholera, infectious hepatitis (caused by hepatitis A virus [HAV] or HEV), and disease caused by *Shigella spp.* and *E. coli O157* (WHO,2004). The excessive contents of N and P in receiving water bodies lead to extensive algal blooming usually known as eutrophication causing structural changes in ecosystems through increased production of algae and aquatic plants, declining of fish species, deterioration of water quality, and other effects that reduce and preclude the use Meybeck *et al*. (1989).

Disposal of untreated PPWW on land leads soil pollution due to the accumulation of pollutants on the topsoil. Gerber*et al*. (2005) stated that nitrogen pollution has been identified as posing a risk to the quality of soil and water as nitrogen in its nitrate form is mobile in soil, can easily be leached

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into ground water below the rooting zone. The excessive levels of N in the environment lead to a cascade of effects including decreased species diversity and acidification of non-agricultural soils due to nitrogen deposition related to ammonia and N_2O emission (Erisman *et al*, 2001). The rapid growth of intensive poultry production in many parts of the world has created regional and local P imbalances too. Thus, discharge of PPWW without removing these contaminants might cause multi-directional adverse impacts on several key elements of the receiving environment of water, land, and air.

In addition, discharge of untreated poultry processed wastewater may lead to increased atmospheric temperature and subsequent issues of global warming due to gaseous emissions of CH_4, CO_2, and N_2O which are globally identified as GHGs associated with anaerobic degradation in low Oxygen or Oxygen free environments. The important feature of GHGs in the atmosphere is that they absorb and radiate downward a large fraction of longer far-infrared wavelengths (8-12μm) warming the earth's surface (Silva,2007). An increase in GHG concentration leads to global warming and subsequent climate change as increased concentration of GHGs in the atmosphere stimulates the atmospheric heat retention capacity.

D. Regulatory requirement of industry wastewater discharge

Treatment of wastewater to comply with the respective disposal norms before discharge is one of the major concerns in the industries worldwide. In Sri Lanka, environmental pollution issues due to industrial discharges are regulated by the National Environmental Act No. 47 of 1980 as amended by Act No. 56 of 1988 and Act No. 53 of 2000. As per the regulation, meat products manufacturing industries are fall under the category of high polluting industries and it encourages treating wastewater to be in compliance with the respective disposal norms prior to discharge in order to control the pollution issues associated with its discharge.

Most of the poultry processing industries are located in the interior of the country with minimum facilities for discharge of industrial waste into marine coastal areas or Public Sewers with Central Treatment Plants, the National Environmental (Protection and Quality) Regulation encourages the poultry processing industries to follow the disposal options indicated in the List I and List II of Schedule I indicated under the Part III; Tolerance limits for the discharge if industrial waste into Inland Surface Waters and Tolerance limits for industrial waste discharged on land for irrigation purpose. The tolerance limit values for the pollution parameters of pH, COD and TSS considered in the study are given in the Table 1.

Table I: Disposal Norm Values Of Pollution Parameters Considered In The Study

Disposal norm	pH at ambient temperature	COD (mg/l)
Disposal norm*	6.5-8.5	250
Disposal norm**	5.5-9.0	400

Disposal norm*: Tolerance Limits for the Discharge of industrial Waste into Inland Surface Waters.
Disposal norm**: Tolerance Limits for the Discharge of industrial Waste on Land for Irrigation Purpose.

E. Treatment and disposal of poultry processing wastewater

Treatment and disposal of PPWW are one of the major concerns in the poultry meat production industries worldwide. Biological treatment methods (aerobic and anaerobic) have been traditionally used for slaughterhouse wastewater treatment (Aziz *et al*., 2018). The overall objective of the biological treatments is to oxidize or convert dissolved and particulate biodegradable constituents into simple gaseous end products, capture and incorporate suspended and non-settlable colloidal solids into biological sludge and transform or remove N and P into its gaseous products.

In many countries, PPWW is mainly treated using aerobic biological methods followed by various physical treatments of solids and oil removal, prior to sending to municipal sewage systems for further treatment. The removal and stabilization of organic matter found in wastewater are accomplished biologically using a variety of microorganisms, principally bacteria (Tchobanoglus *et al*., 2003). The countries concerned with energy conservation while mitigating pollution, ANRBTs are mainly used for the treatment of PPWW as anaerobic degradation processes yield clean energy that can be recovered in the form of Methane with lower volumes of sludge. In the ANRBTs, dissolved and particulate biodegradable constituents convert mainly into simple gaseous end products of Metahne (CH_4), transform N and P into its gaseous products, and generates biological sludge in very small volumes incorporated with suspended and non-settlable colloidal solids. The anaerobic degradation of organic matter to produce CH_4 relies on the complex interaction of three different groups of bacteria; a mixture of fermentative bacteria of acid formers or acedogenices which hydrolyze the complex organic in to short chain fatty acid and alcohols, acetogenises that forms acetates, and hydrogen and Methanogens that coverts to acetates into CH_4 and CO_2 (Gunnerson Stuckey, 1986). The effectiveness, economical, and feasibility of ANRBTs greatly depend on the organic strength of wastewater and its temperature.

However, both biological techniques have some limitations: for example, aerobic treatment processes require high energy consumption for aeration and generate a high amount of sludge (Awang, *et al*., 2011). In addition, AERBT processes reported issues of stressfulness to high organic strengths, the larger space requirement for the erection of treatment while enabling no energy recovery. The anaerobic treatment process of the poultry slaughterhouse wastewater is often impaired or slowed down because of the accumulation of suspended solids and floating fats in the reactor, which in turn leads to a reduction in methanogenic activity and biomass washout (Kobya, *et al*.,2006).

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II. Materials and Methods

A. Material

1) Test Samples: The test samples of untreated PPWW of individual PPIs were collected from the process wastewater collection tank of each industry, for laboratory analysis to determine characteristics in terms of pH and COD.

2) Laboratory analytical instruments or equipment: A benchtop pH meter and a COD test kit of HACH colorimeter were used to measure the pollution parameters of pH and COD of the field samples of PPWW collected from the selected samples of PPIs, respectively.

B. Methods

The study was designed as a combination of a field survey and a laboratory experiment followed by a comprehensive information search among industry samples of two selected industry categories; PFP and PFFP industries in operation over the country. Only PFP and PFFP industries were considered for the survey since the poultry industries that carry only the poultry further processing do not use water in significant amounts.

C. Field survey

The field survey was conducted across a selected sample of 07 PFPIs and 05 PFFPIs. Out of the selected samples of 07 PFPIs and 05 PFFPIs, only 05 PFPIs and all 05 PFFPIs fall under the large scale category. The survey included live data gathering on the industry operation, untreated PPWW sample collection for laboratory analysis, and collection of technical specifications on the PPWW treatment facilities and TWW disposal practices.

D. Sample collection and laboratory analysis

The method of grab sampling was followed in the collection of field samples of untreated PPWW for laboratory analysis. Laboratory analysis was carried out according to the laboratory analytical methods in the APHA (2005): Standard Methods for the Examination of Water and Wastewater. The specific analytical methods used in the analysis of field samples for the selected pollution parameters of pH, COD, and TSS are APHA 4500, Modified APHA 5220D-Colorimetric method using HATCH DR/890 and APHA 2540D respectively.

III. Findings and Discussion

A. Operational status of Poultry processing industries

The field survey investigated that all the PFP and PFFP industries subjected to the study are equipped with wastewater treatment facilities operated on various treatment techniques. The current operational status of the selected sample of PPIs viz. PFP and PFFP industries identified during the field survey are summarized in Table 2.

The production based water usage of local PPIs subjected to field survey largely varies one another within a wide range of (05-14) liters for processing of one bird in the PFPIs and (11-30) liters/bird in the PFFPIs (Table 2). The discrepancy of water usage (per bird water usage) taken place within the same category of industries even with similar production capacity is mainly due to different process operational practices in place and the water use minimization approach of individual industries. The daily basis total water usage in a poultry production plant accounts to the water usage in the birds processing, production floor washings and the equipment cleaning. Thus, a wide variation of daily discharge rate of PPWW too was reported among the same industry categories in similar manner reflecting a daily WW discharge rate of (330-690) m3/day in PFFPIs and (30-280) m3/day of WW discharge rate in the PFPIs. This discrepancy in the daily discharge rates of wastewater is mainly due to the various manual operational practices of equipment cleaning and floor washings in individual industries.

Further, Table 2 shows unsatisfactory surrounding ambient air quality conditions in the majority of the PPIs considered for the survey (more than 78% of the PPIs) due to the release of malodorous volatile organic compounds (VOCs) (except WWTFs in 03 PFFPIs operated on ANRBTs) ensuring unsatisfactory treatment performance of existing wastewater treatment facilities. This might mainly be due to blowing off of surrounding air with VOCs resulting from aerobic biological and chemical treatment facilities that are in operation at inappropriate operational conditions under the open air.

B. Characteristics of poultry processing wastewater

The characteristics of untreated PPWW of PFPIs and PFFPIs subjected to field survey are summarized in Table 3, as determination of organic strength characteristics of untreated PPWW in terms of COD was one of the primary aims of the study.

The parameter pH; which is one of the most critical and basic parameters used to determine the major characteristics of any wastewater, of untreated PPWW collected from the entire series of poultry processing industries considered for the field survey, lies within the range of 5.2-6.9. Also, Table 3 shows that the most featured pollution parameter of COD, which is one of the basic parameters that used to interpret the organic strength of wastewaters, of untreated PPWW samples of PFPIs is significantly high and varies largely within the range of (1,605 – 9500) mg/l. The same parameter of COD of untreated WW collected from PFFPIs is higher than that and varies within a comparatively higher range of (3,750 – 14,000) mg/l. This clearly interprets the high strength organic characteristics of PPWW and it proves the highly polluted nature of wastewaters that generates from poultry processing operations. Also, these COD might be nearly similar to its biodegradable COD as the most of the organic compounds in PPWWs are contributed from biodegradable organic materials made up of proteins, fats, and oils etc. However, the large variation of COD of PPWW shown in both the categories of PFPIs and PFFPIs is mainly caused by the waste meat/material losses and uncollected blood in the waste streams due to poor housekeeping practices.

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Table II: Operational Status Of The Surveyed Poultry Processing Industries In Sri Lanka

Industry ID	Average production (Birds/day)	Water use (liters/bird)	***Process WW discharge (m^3/day)	Availability of WWTF (Yes or No)	WWTF is of bad odorous? (Yes or No)
PFP1	20,000	05	100	Yes	Yes
PFP2	20,000	14	280	Yes	Yes
PFP3	20,000	05	100	Yes	Yes
PFP4	15,000	12	180	Yes	Yes
PFP5	8,000	05	40	Yes	Yes
PFP6	3,000	12	36	Yes	Yes
PFP7	4,000	7.5	30	Yes	Yes
PFFP1	30,000	11	330	Yes	Yes
PFFP2	25,000	15	375	Yes	Yes
PFFP3	25,000	14	350	Yes	**No**
PFFP4	23,000	30	690	Yes	**No**
PFFP5	20,000	22.5	450	Yes	**No**

Source: Field Survey
ID: Identification, WW: Wastewater, WWTF: Wastewater Treatment Facility
**Process WW discharge: Process WW generated from PP operations excluding WW from floor and equipment cleaning.

Comparison of above mentioned COD values with past experimental data is not possible as no comprehensive local literature is available, especially the studies done separately for the PFPIs and PFFPIs, due to lack of scientific investigations done for local PPWW in the past. However, comparison of PPWW characteristics were reported in the international literature of Arvanitoyannis Ladas (2008) and Merka (1989), reported COD of (3980 – 7120) and average COD of 3772 mg/L respectively in the PPWW, irrespective of the category of PPI, reflects nearly closer to the local levels. Further, Table 3 shows comparatively high TSS contents in the untreated wastewater samples drawn from both the industry categories of PFPs and PFFPs and it varies within the range of (365-2,480) mg/l in the PFPIs and (460 – 4,050) mg/l in the PFFPIs. This reflects high TSS concentrations in the PFFP industry wastewaters compared to the PFP wastewaters. Also, variation of TSS indicated in Table 2.3 indicates good housekeeping practices to reduce meat material losses in place in a very few industries while significant meat material losses to waste streams in the majority of the industries.

Comparison of local and international characteristics of PPWW in terms of TSS of (365-2,480) mg/l and TSS of (285-2660) mg/L (Arvanitoyannis Ladas, 2008) respectively, reflected nearly a similar situation.

C. *Treatment of poultry processing wastewater*

The field survey investigated that all the PFP and PFFP industries selected for the study are equipped with wastewater treatment facilities operated on either continuous or batch mode. In-depth evaluation of that wastewater treatment facilities identified the application of various treatment techniques of AERBTs, CHETs, and ANRBTs as the main piece of treatment technology, immaterial with the organic characteristics of PPWW. Also, all those treatment processes were incorporated with preliminary treatments of screening and floatation prior to the main treatment process to remove large solid particles and lightweight floating matter. Evaluation of the physical treatment processes of floatation found the application of Dissolved Air Floatation (DAF) equipment in all the treatment facilities available with the physical treatment of floatation. The basic features explored on the treatment facilities; treatment techniques applied and the TWW disposal practices are summarized in Table 4.

Evaluation of the wastewater treatment detail of PFP industries (Table 4) found only one (01) PFP industry (PFP3 out of 07 PFPIs) that utilizes anaerobic biological degradation as the basic piece of treatment technology which has fundamentally established as the most appropriate technique for the treatment of wastewaters with high organic strength characteristics. In this system, incorporation of physical treatment of a screening step prior to anaerobic biological degradation

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Table III: Characteristics Of Untreated Ppww Discharged From Pfpis And Pffpis.

Industry ID	pH at ambient Temperature	COD (mg/l)	TSS (mg/l)
PFP1	5.9	9,500	2,480
PFP2	5.9	5,100	1,250
PFP3	6.2	4,760	1,250
PFP4	5.9	6,011	1,265
PFP5	6.4	2,600	940
PFP6	6.4	1,756	515
PFP7	6.2	1,605	365
PFFP1	5.2	3,750	1,080
PFFP2	5.6	5,400	1,070
PFFP3	5.7	14,000	4,050
PFFP4	6.2	4,500	1,060
PFFP5	6.9	9,200	460

Source: Field Survey

and a maturation pond after anaerobic degradation as a polishing step has made the treatment process complete, hence, compliance of TWW with respective disposal norms.

It also revealed the application of aerobic biological degradation process alone with physical treatments – and one with a chemical treatment, by the majority of the PFPIs (04 out of 07) raising the question of TWW quality compliance with respective disposal norms. Fundamentally, the aerobic biological treatments stabilize the wastewater through the removal of dissolved and particulate carbonaceous material by aerobic microbes and are quite applicable for the degradation of wastewaters of low organic strength since aerobic degradation is stressful for high organic strength characteristics. The wastewater with biodegradable COD at 1300 mg/l or less, aerobic treatment alone may be the preferred selection for effective reduction of COD to comply with the disposal norm value of 250mg/l. Therefore, application of aerobic biological degradation as the main treatment technique for the treatment of PPWW of high organic strengths is questionable to some extent in the context of maintaining the quality compliance of TWW with the respective disposal norm specified for Inland surface waters.

Apart from biological treatments, the application of chemical treatments alone with physical treatment, by two (02) PFPIs was revealed. Principally, chemical treatments are used for the reduction of COD contributed from colloidal material and/or suspended solid materials associated with any wastewater by promoting destabilization of stable colloidal compounds forming a sludge that could be removed from the solution by gravity separation. Hence, the application of CHETs for the stabilization of PPWW may not be much effective in the reduction of biodegradable COD contributed from dissolved organic compounds in the PPWW. Thus, the treatment performance required to comply with the respective disposal norms is hardly expected through the application of CHETs alone. Therefore, the application of chemical treatments for the treatment of PPWW is highly questionable. Accordingly, the TWW quality compliance with the respective disposal norms is also questionable.

Similarly in the PFPIs, the field survey findings of PFFPIs reported in Table 4 found the application of anaerobic biological degradation (followed by aerobic biological degradation as the polishing process) only in three (03) PFFPIs out of 05 PFFPIs which considered to be the most appropriate and feasible technology for the treatment of PPWW with high organic strength characteristics, as per the fundamental approaches and basic principles on the anaerobic digestion of high strength wastewaters. In addition, the empirical literature has also explored the feasibility of applying an anaerobic digestion approach for the stabilization of waste with high organic strengths represented by high COD since anaerobic digestion reduces high COD into high energy recoverable in the form of Methane while yielding a less volume of sludge. Tchobanoglus *et al*. (2003) emphasized that a considerable reduction of COD within the range of (75-90) percent assuring that ANRBTs are effective and efficient pre treatment that facilitates disposal of high strength wastewaters. Appropriate operation and maintenance of such treatment systems

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Table IV: Treatment Techniques And Disposal Practices

Industry ID	Treatment technique	TWW disposal practice
PFP1	Screening, DAF, Aerobic biological degradation[1]	Discharge on land for IRRIG
PFP2	Screening, Aerobic biological degradation[1]	Discharge into nearby waters[3]
PFP3	Screening, Anaerobic biological degradation Maturation pond	Discharge on land for IRRIG
PFP4	Screening, Chemical treatment[2], Aerobic-biological degradation[1]	Discharge on land for IRRIG
PFP5	Screening, DAF, Aerobic biological degradation[1]	Discharge on land
PFP6	Screening, Chemical treatment[2]	Discharge into nearby waters[3]
PFP7	Screening, Chemical treatment[2]	Discharge into nearby waters[3].
PFFP1	Screening, DAF, Aerobic biological degradation[1]	Discharge into ISWs[4]
PFFP2	Screening, DAF, Aerobic biological degradation[1]	Discharge on land
PFFP3	Screening, Anaerobic biological degradation, Aerobic biological degradation[1]	Discharge on land
PFFP4	Screening, Anaerobic biological degradation, Aerobic biological degradation[1]	Discharge on land
PFFP5	Screening, Anaerobic biological degradation, Aerobic biological degradation[1]	Discharge on land for IRRIG

Source: Field Survey

IRRIG – Irrigation, Aerobic biological degradation1: Aerobic biological treatment system operated on activated sludge mode where removal of organic material is accomplished by means of micro-organisms adopted on suspended growth mode, in the presence of oxygen., Chemical treatment[2]: chemical coagulation and flocculation, Discharge into nearby waters[3]: Discharge into nearby water causes through stormwater surface drain network., Discharge into ISWs[4]: Directly discharge into Inland Surface Waterbodies.

lead to continuous compliance of TWW quality with the disposal norm specified for inland surface waters. However, theoretically, anaerobic reactors in operation without a top cover might lead to poor treatment performance though it remains virtually anaerobic. The subsequent treatment of aerobic digestion will also then be less effective.

D. Disposal of treated wastewater

The field survey on the selected samples of PPIs identified that the majority of the PPIs around 08 out of 12 industries follow the TWW disposal option of "application on land for irrigation purposes", out of which only 04 of those industries are utilized TWW for irrigation/cultivation purposes in reality and the rest of the 04 industries are just disposed their TWW on lands for the sake of disposal that would otherwise become valuable lands with high economic values. Also, most of the lands that have been used for the disposal of treated PPWW seemed to become marshy with wild plants grown on due to haphazard and continuous disposal of TWW without any cultivation/irrigation system. This inappropriate disposal of TWW might be expected due to non-compliance status of TWW quality with respective disposal norms resulting in unsatisfactory treatment performance. However, this may lead to various issues on land pollution and subsequent groundwater contamination. Further analysis of the rest of 04 PPIs revealed only 01 PFFPI discharge TWW into Inland Surface Waters whereas other 03 PFFPIs discharge TWW into nearby water causes via surface drains without knowing whether it ends up in an Inland Surface Waters or somewhere else. This might also lead to pollution issues in case of partially treated or poorly treated wastewater discharge if receiving waters are at low flow conditions.

The National Environmental (Protection and Quality) Regulation encourages the poultry processing industries to discharge treated wastewater in compliance with the disposal norms of "Tolerance limits for the discharge if industrial waste into Inland Surface Waters" and/or "Tolerance limits for industrial waste discharged on land for irrigation purposes" since most of the poultry processing industries are located in the interior to the country with minimum facilities for discharge of waste into marine coastal areas or Public Sewers with Central Treatment Plants. As stipulated, the industries that follow the disposal norms of "Inland Surface Waters" or "Irrigation Purposes" must be maintained their TWW COD at 250mg/l or below or at 400mg/l or below respectively (Table 1).

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IV. Conclusion

High COD (>1605mg/l) of field samples of untreated PPWW assured its high biodegradable organic strength characteristics and ensures the potential applicability of anaerobic biological degradation for the treatment/removal of biodegradable organic pollutants in the entire range of PPWWs. Implementation of anaerobic biological treatment systems will be the most promising option for the treatment of process wastewater discharged from local Poultry processing industries. Incorporation of anaerobic treatment or kind of a polishing treatment will be much effective in achieving the disposal norm specified for the inland surface waters. The continuous disposal of TWW in a haphazard manner on land without applying an appropriate irrigation method may lead unsafe disposal resulting to various issues on land pollution and subsequent issues of ground water contamination.

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VI. Authors' Contribution

Author 1 designed and conducted the study, performed the statistical analysis, wrote the protocol, and prepared the first draft of the manuscript. 'Author 2' and 'Author 3' reviewed the draft paper and approved the final manuscript."

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